

Conference Paper

Criteria for the Development and Evaluation of the Implementation of a Sustainable Pedestrian Bridge

H. Hendrawan*¹ and S. Amelia²¹Research and Development Agency of West Java Province, Bandung, Indonesia²Directorate General of Bina Marga, Ministry of Public Works and Housing, Jakarta, Indonesia**ORCID ID**Hendra Hendrawan: <https://orcid.org/0000-0002-8406-6677>**Abstract.**

The Pedestrian Bridge (Indonesian: JPO) is a vital facility to reduce traffic conflicts and accidents. There is a need to optimize the use of JPO while encouraging sustainable infrastructure development. This requires sustainability criteria. This study aimed to develop and evaluate the implementation of a sustainable JPO criteria in Indonesia by constructing an "eco JPO" prototype in Surakarta City. A qualitative and quantitative descriptive questionnaire instrument in the form of a Likert scale was used, and further analysis was done using interest performance analysis. The results showed that two criteria must be met, namely, planning criteria and design criteria. Planning criteria included suitability to people's needs and location. The design criteria included seven measures: attractive design, environmentally friendly, energy self-sufficient, safe, artistic, comfortable, and safe. Based on the evaluation of the design criteria, the overall JPO criteria relatively had the same importance value, namely "important" with values between 4.47 - 4.85, and weights between 5.8% - 6.57%. The satisfaction aspect showed a somewhat similar value, namely "satisfied" with the grade between 3.67 - 4.61, and weights between 5.45% - 6.73%.

Keywords: Sustainable, pedestrian bridge, criteria

1. INTRODUCTION

Through the National Road Safety General Plan 2011-2035, the Republic of Indonesia's Government seeks to reduce the death rate and losses caused by accidents [1]. One of the efforts made is through the provision of safe facilities and infrastructure. Efforts to provide facilities and infrastructure are made for motorized vehicles and all road users, including pedestrians. Pedestrians are still vulnerable to accidents so far. Globally, 22% of accidents involve pedestrians [2].

The factors that cause the high accidents involving pedestrians besides human neglect of both drivers and pedestrians are that the Pedestrian Bridges (in Bahasa Indonesia: JPO) are not yet available or have not been used optimally [3,4]. The

Corresponding Author: H.
Hendrawan; email:
hendra2wan@gmail.com

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pedestrian bridge based on the study results showed that usage was low, where the community still had a tendency to cross the road without using crossing facilities, including JPO. Some of the causes of the low utilization of JPO are uncomfortable, dirty, insecure, unattractive, and long distances [4–9]. The JPO is typically designed with a rigid and conventional design.

The change in JPO from conventional design concepts needs to be changed to JPO with a sustainable idea, which includes accessibility, aesthetics, and local wisdom [10]. Accessibility provides equality and comfort for people who have special needs or have limited physical abilities in terms of age, sensory capability, and limb limitations [11–13]. Aesthetics also play an essential role in design to attract users to take advantage of JPO [7,14]. Aesthetics reflects the region's character, harmony with the environment, and media for the community to interact [15,16]. The local wisdom or culture shows the local culture where the JPO must have a theme based on agreement or community characteristics [17].

Standards and guidelines in Indonesia do not yet have specific criteria for sustainable JPO. Existing standards and guidelines only govern general technical provisions with rigid and modest designs [18]. The study of the development and application of the JPO conducted by the Institute of Road Engineering (IRE) in 2017-2019 is expected to provide input on the criteria needed for optimal JPO utilization while delivering value to the community and the natural environment. It is hoped that the implementation of sustainable JPO criteria for JPO in Indonesia can help the government reduce traffic conflicts and accidents and provide facilities with more value to the environment and society.

2. METHODS

In general, this study was carried out with several stages of activities as follows:

1. A literature review was done by digging up information about concepts, ideas, rules, or the results of implementation relating to sustainability, mainly to improve the use of JPO and the development of an aesthetic and environmentally friendly JPO.
2. Discussion with resource persons or experts in the field of environment and traffic; planners; road organizers; and stakeholders in the Surakarta City officials related to the surroundings; obtain input on the criteria needed to develop sustainable JPO concepts that would be applied to the JPO.

3. The preparation of the physical design of the JPO construction is by taking into account the sustainable criteria that have been formulated.
4. JPO Prototype was developed in the selected location. The location is in front of dr. Moewardi Hospital on the Kolonel Sutarto Road in Surakarta City. Construction was carried out in a self-managed construction type from February 2018 to June 2019.
5. Evaluate sustainable criteria after the JPO was operated to determine the level of importance and satisfaction with the requirements. The evaluation was conducted using an instrument in the form of a validated and reliable questionnaire distributed to 60 respondents who were chosen accidentally. Data were collected on weekdays and weekends in the morning (06.30–08.30) and afternoon (15.30–17.30). The scale used for the level of satisfaction and importance can be seen in Table 1.

TABLE 1: The grading scale of satisfaction and importance.

Scale	Level of Satisfaction	Level of Importance	Score
1	Very Dissatisfied	Very Unimportant	0.00-0.34
2	Dissatisfied	Unimportant	0.35-0.05
3	Not Sure	Not Sure	0.51-0.65
4	Satisfied	Important	0.66-0.80
5	Very Satisfied	Very Important	0.81-1.00

3. RESULTS AND DISCUSSION

3.1. Planning Criteria

Based on the results of the study, an important thing to consider in the provision of JPO before design and development stages is through the planning stage, which consists of needs and site selection analysis [14,19,20]. The needs analysis in this study was needed so that the JPO was worth providing optimal benefits to reduce the potential accidents and increase pedestrians' accessibility and mobility safely and comfortably. Based on the study results, there were broadly two essential things for the needs of JPO, namely government policies to support regional planning and connectivity between regions or transportation nodes and approaches to prevent traffic conflicts or accidents [12,13,21].

In this study, the needs analysis was determined based on policies to reduce traffic conflicts. Needs were assessed based on pedestrian volume and the square of vehicle volume during peak hours. The survey results and data processing for the JPO location plan on the Kolonel Sutarto show that the product of the pedestrian volume and the square of the vehicle volume are above 2×10^8 . Based on the Guidelines for Pedestrian Facility Planning [13], it can be concluded that the JPO on Kolonel Sutarto Road is feasible or meets the established criteria. Then based on these conclusions, it can be continued at the site selection analysis stage.

The principle in site selection is needed to obtain an ideal location for the placement of JPO on Kolonel Sutarto Road. The site selection criteria are as follows:

i. General requirements

- In clear and dispute-free land acquisition status
- Following the spatial plan or urban area development plan
- Following environmental permits
- Following building permits

2. Technical Provisions

- The maximum distance from the activity center, the crowd, and bus stops are not more than 50 m
- The minimum distance from the crossings are not less than 50 m
- Distance from the same-level of crossings are not less than 180 m
- Distance from the different-level of crossings are not less than 400 m
- Located on flat terrain with road slope not more than 3%
- Connected with sidewalks and the adjacent transportation node
- Does not reduce the effective width of the sidewalk and the width of the road lane

Based on an analysis, the JPO location in front of dr. Moewardi Hospital has fulfilled all of the requirements in terms of location criteria.

3.2. Design Criteria

The next stage was the design criteria analysis after meeting the planning criteria. Design criteria analysis was carried out so that the JPO design results followed the technical standards or guidelines set by the government or the authorized agency. In addition to the design criteria, the elements needed to support sustainability could be applied through the physical, architectural, mechanical, and electrical design of the main building or supporting facilities. Of course, the design must pay attention to costs as an essential part of the sustainable concept [22,23].

Based on the study results, three general technical criteria must be met in every JPO development, both JPO with conventional concepts or JPO with sustainable concepts [24]. These general criteria were:

1. compliance with building and environmental plans. It was intended to create a diversity of land uses that were balanced, mutually compatible, and integrated and created an aesthetic character, showing the image of the area and ecological insight with a comfortable, safe, and healthy environment.
2. compliance with the bridge's basic design (structural safety, durability, workability, inspectability, maintainability, rideability, and safety).
3. compliance with bridge design standards or guidelines [13,18,25–31].

Based on general technical criteria, the main and additional facility criteria, and from various inputs, it can be concluded that there were 7 (seven) criteria that must be met in the design of a sustainable JPO, namely:

1. attractive in the form of landscaping, architecture (selection of colors and shapes of buildings), and the provision of supporting pedestrian facilities;
2. environmentally friendly through the use of materials that are environmentally friendly and energy-efficient, and the reuse of natural resources;
3. self-sufficient energy including the use of renewable energy resources;
4. artistic including contemporary architectural designs (modern) or designs that show the local culture/wisdom;
5. comfortable including the height design steps, ramp lines, shade/roofs, and the distance to other facilities that meet the requirements or standards;

6. safety, including the design of safety fences, signs, and other facilities that meet the needs or standards.

The general provisions of the design for JPO based on the standards and design guidelines in Indonesia can be seen in Table 2.

TABLE 2: General technical criteria for design components in JPO.

Design Component	General Technical Criteria
Age of the bridge	Min. 50 up to 75 years
Bridge floor	height of the clearance area at the bottom of the bridge floor to the road surface is 5.1 meters
Sidewalk	sidewalk width on the bridge at least 2 meters
Bridge fence	Minimum fence height is 1.2 meters In the longitudinal part of the end of the fence, given an additional length of 0.3 meters
Bridge ramp	The maximum slope is 8% Maximum slope length of every 9 m is equipped with a flat platform with a span of 1.2 m - Equipped with a handrail with a height of 0.8 meters
Bridge stairs	Maximum ladder slope of 20° (on land with a maximum slope permitted is 35°) The height of steps is 15-21.5 cm The width of steps is 21.5-30.5 cm The product of height and width of steps is 450-480 cm ² Minimum length overlap width of stairs is 10 mm Recommendation number of stairs until landing stairs is 13-18 steps. Minimum runway stair width is 1.2 meters
Bridge roof	The roof height is at least 2.5 meters from the bridge floor surface
Drainage	Drainage regulations refer to the guidelines for the design of bridge drainage [32] 10-year plan of rain period Minimum 50% of rainwater catchment can be reused or absorbed into the ground
Landscaping	The landscape on the bridge for placement and selection of plant species refers to the Minister of Public Works Regulation [33]

The criteria for the types of facilities that meet the sustainable concept are shown in Table 3.

3.3. Evaluation of Level of Satisfaction and Criteria Importance

The profile of 60 respondents who assessed the criteria' satisfaction and importance was dominated by men (63%), 21-40 years old (47%) (<15 years old: 0%; 41–50 years old: 20%; >50 years old:18%), and migrants from other cities (51%) (indigenous people of Jebres District: 17%; migrants from other districts: 15%; migrants from other provinces: 17%). Many migrants from other cities were due to hospitals and bus stops, where people generally came to visit hospitals and use bus stops as a means of public transportation.

The data processing results for the level of satisfaction and importance of sustainable JPO criteria can be seen in Table 4. Based on Table 4 below, it can be seen that the comparison between the level of satisfaction and importance was in the range of 0.80 to

TABLE 3: Criteria for the main and additional facilities of JPO with a sustainable concept.

No.	Type of Facilities	Criteria of Facility
I	Main Facility	
	Power source	It is recommended that a minimum of 50% of electricity consumption be used for the operation of facilities and maintenance of bridges (outside for elevators) sourced from renewable energy such as solar, wind, and water. The amount of electric power capacity is calculated based on the needs
	Lighting	Lighting on JPO must meet luminance standards, evenness of illumination, and illuminance that meet health standards on various functions and classifications of locations.
	Guide path	The guideline refers to circular No. 02/SE/M/2018 [13]
	Markings /signs	The guideline refers to the regulation of the Minister of Transportation regarding markings and signs.
	Infiltration wells	One unit is put on each side of the bridge. The capacity of the infiltration well is adjusted to the debit and the area of the bridge.
	Elevator	An elevator is provided if there is not enough land to provide a ramp. Lift capacity and its area are calculated based on the estimated number of users, especially for users with limited abilities.
II	Added Facility	
	Garden	At least 30% of the area is a green area
	Trash can	A minimum of 2 bins are provided on both sides of the bridge access
	Charger station	At least 1 unit of the charger station is available
	Surveillance camera	At least one that leads to the main span corridor of the bridge
	Bench	A minimum of 1 seating unit with a width of 40-50 centimeters and a length of 150 centimeters

0.98, with an average of 0,91. This value shows that the user’s perception of sustainable criteria in JPO was considered very important and very satisfied in its implementation.

Satisfaction and importance value with the highest value, either the score or the weight score, was on the availability of shade/roofs. The shade/roofs were designed higher than 2.5 meters (4-5 meters). A high roof design was needed so that air could circulate adequately. Another plus point was that the user could freely move and had a free view, while the plants could be watered by rainwater to reduce dependence on well water. A large roof covering all areas used by pedestrians provided a sense of security and comfort.

The lowest satisfaction of the criteria was in the plant landscape. Several things, including trash and cigarette, caused the low assessment ends thrown into the park, dead and untreated plants, and damage to ornaments due to vandalism. Efforts were

required from all parties, including providing adequate trash cans, routine watering, maintenance, supervision, and information provision regarding the importance of maintaining public facilities.

From the aspect of importance, cultural ornaments have the lowest score even though it is still critical. Artistic ornamentation was a form of art that represented an area's local wisdom; for example, this JPO was the puppet ornaments. This ornament would undoubtedly vary according to the region, and each part would have a superior culture compared to existing cultures. Of course, the community considered that the ornaments would depend on the local government's policies. Thus, the shape and variety of artistic ornaments couldn't be intervened due to different views on what should be in the JPO.

Another aspect that is seen as satisfied and essential but has a low importance value is the use of LEDs. The community believed that the lighting from public street lighting and vehicles was enough to illuminate the JPO at that location. But of course, it would depend on the condition of the site where JPO was located. Thus, the LED lights' quantity and power must be well designed to provide comfortable lighting for the users.

Compared to other research results, we found the same criteria valued as essential variables influencing people to use the pedestrian bridge. Those criteria are related to the aspect of comfort and safety. Users will feel comfortable and safe to use the pedestrian bridge if elements of the structure are well designed or maintained, such as the floor, roof, fence, stairs, and light [6,11,14,34,35]. Another element that should be considered to be built for supporting safety, which was not included in this research, is the median guardrail, which will prevent undisciplined pedestrians from crossing under the bridge [35].

4. CONCLUSION

Based on the study results above, JPO will be considered sustainable if it meets the planning criteria and the design criteria. The planning criteria include suitability to location and needs. The design criteria include fulfillment of general technical criteria and facility criteria summarized in 7 criteria: attractive design, environmentally friendly, self-sufficient energy, safer, artistic, comfortable, and safe. All of the prototype criteria based on the evaluation results have a high-performance level and importance.

From the results of this study, further studies need to be carried out to assess the JPO utilization level. The assessment needs to be done to measure the JPO

TABLE 4: Level of satisfaction and importance of sustainable JPO criteria.

Score in Level of Satisfaction				Score in Level of Importance			Comparison of the level of satisfaction and importance	
Number and Criteria of Sustainable JPO	Average	Total Score	Weight (%)	Average	Total Score	Weight (%)		
JPO is designed with an attractive concept								
1	The existence of Landscape in JPO (includes artificial and natural, concerning aesthetic aspects) including Green Open Space							
		3.6 (min)	220	5.45 (min)	4.57	274	6.19	0,80 (min)
2	Availability in supporting facilities. Such as plants, chairs, charger stations, and trash cans.	4.15	249	6.16	4.72	283	6.39	0,88
JPO is designed with an environmentally friendly concept								
3	Utilization of rainwater stored in groundwater tanks to water plants	3.93	236	5.84	4.65	279	6.30	0,85
4	The use of energy-efficient LED lamps	4.44	231	5.72	4.85	257	5.80 (min)	0,90
JPO is designed with an independent energy concept (Energy Self Sufficient)								
5	The use of solar panels for lighting the main span of the JPO	4.35	261	6.46	4.77	286	6.46	0,91
JPO is designed with a safer concept								
6	Application of 4 CCTV equipment in the JPO area	4.39	259	6.41	4.80	283	6.39	0,92
7	Lighting lamps with standard lighting	4.40	264	6.54	4.57	274	6.19	0,96
JPO is designed with an artistic concept								
8	Cultural ornaments	4.39	259	6.41	4.47 (min)	264	5.96	0,98 (max)
9	Fences with architectural accents that carry local culture/wisdom	4.46	263	6.51	4.61	272	6.14	0,97
10	Selection of colors and shapes of buildings	4.50	252	6.24	4.65	265	5.98	0,95
JPO is designed with a comfortable concept								
11	Design height of stairs, the width of steps, width of the runway, and condition/slope according to walking comfort standards							
		4.10	246	6.09	4.62	277	6.26	0,89
12	Provision of ramp/special lane facilities and elevator facilities for diffable	4.07	240	5.94	4.73	284	6.41	0,85
13	Availability of shade/roofs when it is raining and hot	4.61 (max)	272	6.73 (max)	4.85 (max)	291	6.57 (max)	0,93
14	The bridge has a short distance from the center of activity and the adjacent transportation node	4.47	264	6.54	4.66	275	6.21	0,96
JPO is designed with the Safety concept								
15	The height of the handrail of the bridge is made high, and the gap in the railing is tight	4.41	260	6.44	4.65	279	6.30	0,93
16	There are signs (height of the bridge) and information (prohibit leaning and climbing)	4.38	263	6.51	4.75	285	6.44	0,92
	Total average	4.30	252.4	6.25	4.68	276.8	6.25	0,91
	Min	3.67	220	5.45	4.47	257	5.80	0,80
	Max	4.61	272	6.73	4.85	291	6.57	0,98

provision's effectiveness to evaluate whether JPO with a sustainable concept can influence pedestrians to use JPO when crossing.

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